

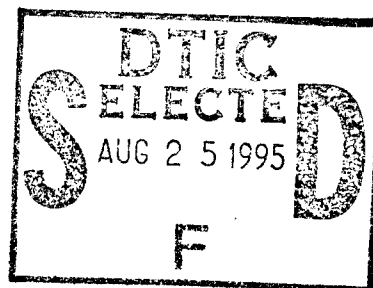
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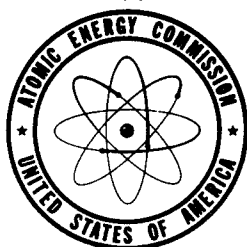
FINAL REPORT ON RETENTION OF  $I^{131}$  BY  
BACTERIAL SLIMES IN DRAINS FOR NOVEMBER  
15, 1949, TO NOVEMBER 15, 1950

By  
Albert P. Talboys



November 15, 1950

The Johns Hopkins University



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# ABSTRACT

This report describes the laboratory investigation of the uptake of  $I^{131}$  by heterogeneous bacterial slimes often present in waste-drain systems. It is one of a series of studies undertaken by the Sanitary Engineering Department of The Johns Hopkins University to explore contamination of waste-line plumbing in institutions discharging radioisotope-bearing wastes.

Since  $I^{131}$ , as iodide, is not metabolized by the slimes, there is little tendency for concentration of the isotope by the slimes. However, the slimes retain small amounts of  $I^{131}$  by physical processes of adsorption and absorption of the active waste liquid. Resultant hazards to maintenance workers who may contact the contaminated slimes were computed from the experimental results and found to be of a very low level.

## INTRODUCTION

### Purpose and Scope of Investigation

The radioisotope in most widespread use in the United States is radioiodine ( $I^{131}$ ). Approximately 20 curies per month are currently being shipped, primarily to hospitals and research laboratories.<sup>1</sup> This amount, although widely dispersed, presents a problem in safe disposal since the isotope emits penetrating gamma rays as well as shorter-ranged beta particles.

A large portion of this radioactive material is disposed of by pouring it into sinks and toilets, to be carried off by the institutional drain system to the sewer. Between sink and sewer the  $I^{131}$  contacts traps, fittings, and piping. The deposition or concentration of sufficient quantities of  $I^{131}$  in parts of the system may constitute a health hazard.

One mechanism by which the  $I^{131}$  might be retained in the drain is adsorption by the bacterial slimes which often line traps and pipes. This project was undertaken to explore this phenomenon, to determine the factors affecting the adsorption and their significance, and to assess the potential hazards arising from the uptake of  $I^{131}$  by slimes in waste-drain systems.

### Previous Work

Research on the uptake of radiophosphorus ( $P^{32}$ ) by similar bacterial slimes was conducted last year for the Atomic Energy Commission at The Johns Hopkins University by G. W. Reid. This study showed that  $P^{32}$  was initially physically adsorbed from waste liquids. After several hours of immersion, however, it was metabolically assimilated by the slimes. Empirical equations were formulated for both processes, and hypothetical health hazards were computed. The results of this work and the present investigation are compared in a later section of this report.

A recent survey of the disposal of radioactive wastes from Massachusetts General Hospital was made by F. A. Butrico at the Massachusetts Institute of Technology. One important observation was that all the active wastes poured into a sink did not immediately drain to the sewer. In fact, 1 hr after disposal, discharges from the sink drain still showed traces of radioactivity, indicating the possibility of retention of the activity by slimes or other mechanisms in the system.

## LABORATORY PROCEDURE

### Growing of Slimes

To obtain uniform bacterial slime growth on relatively inert surfaces, 1- by 3-in. glass microscope slides were continuously dipped into nutrient media. The dipping was accomplished by means of a windshield-wiper motor operating on compressed air. The media consisted of 5 mg of nutrient broth (beef extract and peptone) and 1 ml of glycerol dissolved in a liter of water. The media baths were seeded with heterogeneous bacterial slimes scraped from sink drains in the Sanitary Engineering Department washroom. The pH was maintained between 6.5 and 7.5 by the use of marble chips in the media.

Slime coatings of 0.8 to 0.9 mg/sq cm, dry weight, were used because of their uniform thickness and coverage of the slides. These were obtained in 24 to 48 hr by the dipping procedure. Slimes were also grown on metal slides to compare uptake of  $I^{131}$  by slime-coated metals and by the bare metals. Only two-thirds of each slide, or 12.5 cm per slide, was coated, the upper third being kept clear for handling purposes.

### Immersion in $I^{131}$

To determine the extent of adsorption of the  $I^{131}$  by the slimes, the coated portions of the slides were immersed in aqueous solutions containing  $I^{131}$  as  $NaI^{131}$ . The concentrations of  $I^{131}$  used here ranged from 4.0 to 67.5  $\mu$ c/liter. The pH of the baths was adjusted with dilute hydrochloric acid or sodium hydroxide. Since 150-ml beakers filled to the 100-ml level were used, only the slime-coated portions of the slides were immersed. Continuous contact periods varying from 2 sec to 2 hr were used to simulate various retention periods of wastes standing in traps.

To approximate the condition of frequent periodic flushing of drains, long-period tests were run utilizing the dipping technique. For the latter runs, nutrient broth was added to the solutions to sustain the growth of the bacterial slimes and to minimize the tendency to slough. Stable iodide and iodine were added to some of the solutions to determine the value of isotopic dilution. All experiments took place at room temperature.

Decontamination tests were conducted by first allowing the slimes to adsorb some  $I^{131}$  and then immersing the slides in various rinse solutions. Periodic counts demonstrated the removal of  $I^{131}$ .

### Counting Techniques

To determine the concentration of  $I^{131}$  in the solutions, 1-ml samples of the solutions were pipetted into cupped aluminum planchets. After the addition of a few drops of sodium hydroxide and silver nitrate to precipitate the iodide and prevent the loss of iodine by volatilization, the samples were evaporated under an infrared lamp. The planchets were counted with a horizontally mounted glass-wall Geiger-Mueller tube, previously calibrated by absorption-curve comparison with a National Bureau of Standards radium D + E source.

The slides were "wet counted," permitting the slimes to be used for further tests after counting. The wet-count setup consisted of an upright slotted brass cylinder, a slide holder, and a vertically

mounted glass-wall G-M counter arranged to provide reproducible geometries. The slime-coated slides were always dipped once in a distilled-water bath after removal from an active solution and before counting to remove adhering droplets of solution which could give an erroneously high count or contaminate the counting assembly.

All experiments were run in duplicate, and some were run in quadruplicate. Counts per minute (cpm) read on the scaler were corrected for background and coincidence and converted to micromicrocuries per square centimeter of slime surface exposed to activity ( $\mu\mu\text{c}/\text{sq cm}$ ). Results reported are averages of the readings obtained. No corrections were made for decay except as noted, since most runs were not over 2 hr in duration.

### Stable Iodide Tests

Colorimetric analyses for stable iodide adsorbed by the slimes from strong potassium iodide solutions were made according to the procedure described in the Appendix.

## EXPERIMENTAL RESULTS

### Preliminary Tests

Preliminary tests were run by ordinary chemical procedures to ascertain the extent to which stable iodide is taken up by the bacterial slimes. The results of immersion of slimes in 1000- and in 10,000-ppm solutions of potassium iodide for various periods showed that very little iodide is adsorbed and that metabolic uptake plays an extremely minor role, if any.

Dipping of the slimes in organic dyes demonstrated that negatively charged dyes were preferentially adsorbed, indicating a positive charge on the slimes.

### Adsorption of $\text{I}^{131}$ by Slimes

To investigate the over-all character of the adsorption of  $\text{I}^{131}$  as iodide by bacterial slimes over a 24-hr period, the slimes were dipped continuously in  $\text{I}^{131}$ -bearing nutrient media and counted periodically. The results of runs made with two different concentrations of  $\text{I}^{131}$  are plotted in Fig. 1 on semi-logarithmic paper as uptake in micromicrocuries per square centimeter vs. dipping time in hours.

From the curves in Fig. 1, the adsorption process can be divided arbitrarily into three phases:

1. Instantaneous uptake: although the total amount of iodide adsorbed is small, a considerable percentage of this total is adsorbed almost immediately upon contact.
2. High-rate period: following the initial adsorption the  $\text{I}^{131}$  is taken up at a fairly rapid but gradually diminishing rate during the first few hours exposure.
3. Low-rate period: after several hours of dipping the rate of uptake of iodide is quite low, and equilibrium conditions are approached after 18 or 20 hr.

The initial adsorption probably takes place in the top monolayer, while further uptake, at a lower rate, probably occurs as a result of diffusion through the top layer into the other layers and entrapment of active solution in the interstitial spaces and pores (this is shown more clearly in the section describing variation of uptake with thickness of slime). Any further changes are no doubt due to interchange of interstitial liquid with the immersion solution. There are no indications that metabolism of  $\text{I}^{131}$  enters into the adsorption process.

Table 1 illustrates how the hourly per cent increase in iodide adsorbed falls off after a few hours exposure.

### High-rate Period of Adsorption

The second phase or high-rate period of adsorption was chosen for detailed study of the effects of time, concentration, pH, isotopic dilution, and other factors on the uptake of  $I^{131}$ .

Uniformly coated slides were immersed for a total of 2 hr in aqueous solutions containing various amounts of  $I^{131}$

Table 1—Comparison of Hourly Per Cent Increase in  $I^{131}$   
Adsorbed with Time of Exposure (Concentration of  $I^{131}$  in Solution:  $3.3 \mu\text{c/liter}$ )

Exposure time, hr	Uptake $\mu\mu\text{c/sq cm}$	Per cent increase in uptake
1	56	
2	69	23.2
3	79	12.7
4	86	8.9
5	93	8.1
6	99	6.5
10	114	
11	117	2.6
14	122	
15	123	0.8

and counted at intervals throughout the immersion period. The pH of the solutions was 5.8. A log-log plot of the data as uptake vs. time of immersion is shown in Fig. 2.

The straight-line relationships obtained can be expressed by an equation of the following general form:

$$U = C t^n$$

where  $U$  = uptake of  $I^{131}$  in  $\mu\mu\text{c/sq cm}$

$C$  = constant, function of the concentration of  $I^{131}$  in the solution

$t$  = immersion time, sec

$n$  = constant, slope of graph

For concentrations of  $I^{131}$  varying from 4.0 to 67.5  $\mu\text{c/liter}$  the graphs are essentially parallel, with a slope of 0.163. The empirical equation then becomes

$$U = C t^{0.163} \quad (1)$$

The graphs can be extrapolated to  $t = 1$  sec to evaluate  $C$ , and uptake can then be computed for any contact time up to several hours.

### Variation of Uptake with Thickness of Slime

The depth of a slime covering a surface has no bearing on the instantaneous adsorption of  $I^{131}$ , as illustrated in Fig. 3. However, during longer immersion periods the active solution penetrates the surface layers and diffuses through the slime. Thus, thicker slimes are able to absorb greater volumes of solution, and consequently more  $I^{131}$  is taken up.

Since the thick, lumpy slime coatings of 1.6 to 2.2 mg/sq cm (dry weight) easily sloughed, all experiments throughout the study were run with slimes of about 0.8 or 0.9 mg/sq cm, which more evenly covered the slides. In addition, self-absorption of beta radiation from the inner layers was minimized by using thinner slimes. All computations of uptake were made on an area basis.

#### Variation of Uptake with Concentration of $I^{131}$

Uptake of  $I^{131}$  was plotted against concentration of  $I^{131}$  in immersion solution in Fig. 4, using data obtained from the graphs shown in Fig. 2. With time of immersion as the parameter, the graphs are approximately linear on log-log paper over the range of concentrations from 4 to 67.5  $\mu\text{C}/\text{liter}$  with a slope of one. Therefore uptake is directly proportional to concentration, at least for the low concentrations used in this study.

#### Effect of pH on Adsorption

Variation of pH of the immersion solution was found to have only a slight effect upon the adsorption process. This is shown in Fig. 5. Adjustment over the pH range of 3 to 10 was accomplished by the addition of either dilute hydrochloric acid or sodium hydroxide.

Uptake was consistently higher or lower throughout an entire 2-hr run, depending upon the pH maintained. Under alkaline conditions, adsorption was generally weaker. These rather minor variations in uptake may result from changes in equilibria in the iodide solution.

#### Adsorption of $I^{131}$ from Urine

Since much  $I^{131}$  is discharged in the urine of hospital patients treated with radioiodine, tests were made to compare the adsorption of the isotope from urine and from tap water. Slime-coated slides were immersed in both solutions and counted at intervals over a 2-hr period. The pH of the urine rose upon standing, but was roughly the same as that of the water during the run. The slides were then dipped for an additional 15 hr in the same solutions with nutrient broth added and pH maintained at 7.7. The results, presented in Table 2, show that approximately equal amounts of  $I^{131}$  were picked up from each liquid. Urine salts appear to exert no

Table 2—Comparison of Adsorption of  $I^{131}$  from Urine and Tap-water Carriers (Concentration of  $I^{131}$ : 17.1  $\mu\text{C}/\text{liter}$ )

Immersion time	Urine		Tap water	
	pH	cpm	pH	cpm
3 sec	6.0	33	6.8	28
15 sec		51		63
1 min		61		88
15 min		93		100
1 hr	6.6	92	6.8	119
2 hr		116		107
17 hr	7.7	151	7.7	129

effect upon the adsorption of iodide by slimes.

### Effects of Isotopic Dilution

To determine the effects of isotopic dilution on uptake of  $I^{131}$ , stable potassium iodide in amounts ranging from 20 to 10,000 ppm was added to solutions containing essentially carrier-free  $I^{131}$ . The addition of 1 g of potassium iodide per millicurie of  $I^{131}$  disposed is recommended in the Isotopes Division Circular B-6. This is equivalent to 1 ppm of KI for each microcurie per liter of activity.

The slimes were immersed for various periods and counted, but as shown in Table 3, the addition of stable iodide did not reduce the adsorption of  $I^{131}$  at either low or high pH. These results indicate that there is no appreciable selective adsorption of  $I^{131}$  as  $I_2$ ,  $I_3^-$ , or  $I^-$  from the solution. Therefore, there should be little tendency for the slimes to accumulate and concentrate the  $I^{131}$  itself in drains. It follows from this that uptake of  $I^{131}$  is mainly dependent upon the adsorption and absorption of the solution carrying the iodide, and an important limiting factor in the retention of activity by slimes in drain lines is the volume of active waste which the slimes can absorb.

The addition of 20 ppm of free iodine crystals to the active solutions, along with small amounts of potassium iodide to aid in dissolving the crystals, did not significantly affect the adsorption by the slimes. This indicates further that  $I^{131}$  as free iodine is not selectively adsorbed. However, with 200 ppm of free iodine, slime growth was stopped, the slime took on a

Table 3—Effects of Dilution with Potassium Iodide on Adsorption of  $I^{131}$  by Slimes

A. pH 5.8. Concentration of $I^{131}$ : 17.8 $\mu\text{c/liter}$					
Immersion time	Control, cpm	20 ppm KI, cpm	200 ppm KI, cpm	2000 ppm KI, cpm	10,000 ppm KI, cpm
3 sec	41	51	54	24	38
15 sec	61	110	68	72	78
1 min	101	143	95	119	143
1 hr	187	241	160	249	294

B. pH 10.5. Concentration of $I^{131}$ : 12.1 $\mu\text{c/liter}$					
Immersion time	Control, cpm	20 ppm KI, cpm	200 ppm KI, cpm	2000 ppm KI, cpm	10,000 ppm KI, cpm
3 sec	16	22	9	—	10
15 sec	43	23	49	—	48
1 min	37	44	65	—	34
1 hr	79	90	134	—	81

yellowish color, and the uptake was somewhat higher than the control after the 1- and 2-hr immersions. Following the addition of nutrient broth to the solutions and dipping of the slimes for 17 hr more, the count was found to be much higher than the control. The data collected on these runs are shown in Table 4.

The larger amount of free iodine apparently reacted chemically with the bacterial slimes and acted as a bactericide. The increased uptake of  $I^{131}$  can be explained by the fact that dead cells lose some of the characteristics of living cells, such as selective permeability, and the  $I^{131}$  can enter the cell more readily.

### Comparison of Uptake by Slimes and Bare Metals

Experiments were conducted to find out whether slimes take up more or less  $I^{131}$  than do uncoated metals, such as lead, copper, and galvanized iron. It was found that instantaneous pickup was



greater by the slimes than by the metals. However, with longer immersion the lead and copper adsorbed the iodide at a much higher rate than did the slimes. After a 7- to 8-sec contact, the level of uptake by these metals was greater than that of the slimes. Similar results were obtained with brass. Uptake by the galvanized iron also surpassed that of the slimes, but only after a 4- to 5-min immersion. The lag in initial uptake by the metals is no doubt due in large part to slower wetting of the metallic surfaces. Graphs of these runs appear in Fig. 6.

Table 4—Effects of Dilution with Free Iodine on Adsorption of  $I^{131}$  by Slimes (pH 5.8; Concentration of  $I^{131}$ : 12.0  $\mu\text{C}/\text{liter}$ )

Immersion time	Control, cpm	20 ppm $I_2$ , cpm	200 ppm $I_2$ , cpm
3 sec	11	20	24
15 sec	48	29	42
1 min	54	37	39
15 min	70	61	82
1 hr	76	109	187
2 hr	110	94	291
19 hr*	117	104	608

\*Corrected for decay of  $I^{131}$ .

Results of further detailed study of the adsorption by various metals used in fittings and pipes will be presented in a future report.

#### Comparison of Uptake by Slimes Grown on Metals and on Glass

Findings similar to those reported in the preceding section were obtained when slimes grown on lead, brass, iron, and glass were immersed in solutions containing  $I^{131}$ . The adsorption curves are shown in Fig. 7.

The metal-backed slimes all read higher than the slimes grown on glass slides after 2 min of contact, indicating that active solution penetrated the slimes and  $I^{131}$  was adsorbed by the underlying metals. This was confirmed by the residual counts on the metals following removal of the slimes. Actually, the presence of a slime coating slightly retards the stronger adsorptive action of the metals in the case of  $I^{131}$ .

#### Desorption by Immersion and Dipping in Water

Simply immersing  $I^{131}$ -bearing slimes in tap water removed most of the adsorbed  $I^{131}$  fairly quickly. In Fig. 8, curve A shows that 57 per cent of the radioactive iodine was removed from the slimes in 3 sec. At the end of 2 hr, 87 per cent had been desorbed. In the case of curve B, essentially all the  $I^{131}$  had been removed after 2 hr of immersion.

Repeated dipping of the slimes in tap water, to simulate the flushing action of water running through a trap or pipe, furthered the desorption process. Only 15 min was required to remove all detectable amounts of  $I^{131}$  from the slimes, elutriation of the inner layers of slime evidently being promoted by the agitation. The results are shown graphically in Fig. 9.

### Desorption by Immersion in Various Solutions

To compare the effectiveness of desorption by different solutions, slimes with adsorbed  $I^{131}$  were immersed in tap water (pH 6.8), soapy water (pH 8.0), Alconox detergent solution (pH 9.2), and dilute hydrochloric acid (pH 3.4). The desorption curves in Fig. 10 show that the soap and detergent were no more effective than tap water in removing the  $I^{131}$ , at least without agitation of the solution. The hydrochloric acid retarded the loss of  $I^{131}$  by the slime, indicating again that slightly stronger adsorptive forces exist in acid solution.

### SUMMARY OF RESULTS

The experimental studies show that

1. Bacterial slimes lining waste drains are capable of retaining only a relatively small portion of the  $I^{131}$  borne by liquid wastes contacting them.
2. The processes involved appear to be initially rapid physical adsorption on the surface of the slimes followed by slower absorption of active solution by the bulk of the slimes.
3. The uptake increases exponentially with time. In the low ranges of concentration used in this study, uptake was found to be directly proportional to concentration of  $I^{131}$  in the immersion solution.
4. Thicker slimes absorb a somewhat greater volume of active solution, but slough more easily than thin uniform slime coatings.
5. The iodide ion is neither metabolized nor selectively adsorbed to any appreciable extent by the slimes. Thus, isotopic dilution is ineffective.
6. Sufficient quantities of free iodine kill the bacterial slimes and increase the uptake of  $I^{131}$ .
7. Variation of pH of the immersion solutions exerts a slight effect, acid conditions favoring greater uptake. The presence of urine salts is of no importance.
8. Some metals used in plumbing installations have a stronger affinity for  $I^{131}$  than do bacterial slimes, and the slime coatings actually afford a small degree of protection from contamination to these metals.
9. Desorption of  $I^{131}$  from slimes can be fairly quickly accomplished by rinsing them with water.

### PRACTICAL SIGNIFICANCE

The potential hazards involved in  $I^{131}$  disposal in slimed drains can be approximated from the foregoing experimental results. Equation 1 ( $U = C t^{0.163}$ ), which relates the most important factors, can be used to predict the level of uptake (it is strictly valid only for thin slime coatings on relatively inert surfaces for concentrations of 70  $\mu\text{c/liter}$  or less).

The following cases are presented as examples of what might occur in disposal and of the hazards resulting therefrom.

#### Case I

Assume that a waste containing 50  $\mu\text{c/liter}$  of  $I^{131}$  is in contact with slime in a 3-in. cast-iron service trap for 2 hr without dilution. The uptake by the slime will be 900  $\mu\mu\text{c/sq cm}$ .

*Beta Radiation.* If a plumber or maintenance worker happened to get a portion of the slime coating on his hand, for example, 20 sq cm, there would be 0.018  $\mu\text{c}$  in contact with the skin. Assume the  $I^{131}$  is evenly dispersed over the 20 sq cm and the beta particles penetrate the tissue to a depth of 2.2 mm; then about 4.4 g of tissue will be irradiated. If in every second  $1.46 \times 10^{-4}$  equivalent roentgens

(reps) per microcurie are produced in each gram of tissue,<sup>2</sup> a 10-min exposure would give a dose of 7 mrep. Even with continuous exposure for 1 week, the allowable limit of 1500 mrep/week for hands would not be reached.\*

*Gamma Radiation.* If the same trap were being cleaned out and all the slime coating the wetted area of the trap (406 sq cm), were scraped into a container, about 0.365  $\mu\text{c}$  would be concentrated in the container. At a distance of 1 cm from the substance the intensity of gamma radiation would be 2.65 mr/hr/ $\mu\text{c}$ ,<sup>2</sup> or about 1 mr/hr. Thus it would take 300 hr of exposure at this very close range to obtain the weekly allowable body dosage of gamma radiation. At greater distances the intensity of radiation would be very much less.

## Case II

Assume a cancer patient in a hospital is given a 25-mc dose of  $\text{I}^{131}$ . Within 24 hr, 15 mc is likely to be excreted in the urine. If the urine is collected for analysis and subsequently discharged and the volume is about 1 liter, the concentration of the waste will be 15 mc/liter. If it contacts the 406 sq cm of slime lining the wetted area of the 3-in. trap for 10 sec, 34.8  $\mu\text{c}$  may be retained by the slime.\*\* However, it probably will be flushed down with water, and according to Fig. 9, slime A', a 10-sec flush could reduce this activity by 67 per cent, leaving 23.3  $\mu\text{c}$  in the slime.

*Beta Radiation.* If the situation is the same as in Case I for beta radiation, 20 sq cm of slime on the worker's hand would contain 1.15  $\mu\text{c}$ . This would result in a 10-min exposure of 443 mrep. Irradiation for about 3 1/2 hr would be required to exceed the weekly allowable exposure for hands.

*Gamma Radiation.* For conditions similar to those in Case I for gamma radiation, 61.8 mr/hr would be the gamma intensity at 1 cm distance. Therefore the recommended weekly limit would be attained in a little less than 5 hr of exposure.

It is evident from the preceding examples that under ordinary circumstances slimes in drains are not likely to retain enough  $\text{I}^{131}$  to comprise a hazard of any real consequence. Contact of workers with any residual active solution that may be in the drains, or spillage of this liquid during maintenance work, would probably entail greater danger.

Indications are that some of the metals used in plumbing very quickly and strongly adsorb  $\text{I}^{131}$  and other radioisotopes, resulting in a possible concentration of activity in drains. A later report will deal with this aspect of contamination by active wastes.

\* Limits set by National Committee on Radiation Protection, 1950.

\*\*In arriving at the figure 2.83  $\mu\text{c}$ , the following assumption was made: that uptake is directly proportional to concentration for concentrations as high as 15 mc/liter. Then  $U_2/U_1 = (c_2/c_1)$ ; if  $c_1 = 50 \mu\text{c/liter}$ ,  $c_2 = 15,000 \mu\text{c/liter}$ , and  $U_1 = 285 \mu\text{c/sq cm}$  (10-sec uptake) or 0.116  $\mu\text{c}$ ,  $U_2 = 34.8 \mu\text{c}$ .

COMPARISON OF I<sup>131</sup> AND P<sup>32</sup> UPTAKE BY SLIMES

The more important results of the studies of uptake of radioiodine and radiophosphorus by bacterial slimes found in drains are listed below for comparison:\*

	I <sup>131</sup>	P <sup>32</sup>
1. Processes involved	Nonselective adsorption and absorption of waste liquid	Adsorption plus metabolism after several hours of contact
2. Rate of uptake	Uptake initially rapid but tapers off after a few hours	Uptake continues over long periods; limited by sloughing of slime
3. Mathematical relationships		
(a) Uptake and time	$U = C t^{0.163}$	$U_1 = C' t^{0.298}$ (adsorption) $U_2 = \frac{10(3.398 + 0.012t)}{\text{spec. act.}}$ (metabolic uptake)
(b) Uptake and conc.	$U = kc$	$U = k' c^{0.875}$
4. Magnitude of uptake		
(a) Example 1: Solution of 50 $\mu\text{c}$ /liter in contact with slimes for 2 hr	$U = 900 \mu\mu\text{c/sq cm}$	$U_{\text{total}} = 10,000 \mu\mu\text{c/sq cm}$
(b) Example 2: Solution of 2 mc/liter in contact with slimes for 10 sec	$U = 11,400 \mu\mu\text{c/sq cm}$	$U_1 = 41,620 \mu\mu\text{c/sq cm}$
5. Isotopic dilution	Ineffective	Effective only in reducing metabolic uptake of P <sup>32</sup>
6. Desorption	Easily and fairly quickly accomplished by water rinse	Desorption of metabolized P <sup>32</sup> difficult
7. Hazard involved	Very little	Generally little, but can be appreciable under extreme conditions

## APPENDIX

## Analytical Procedure for Determining Iodine in Organic Slimes\*\*

The slime-coated slide is first dried in the oven for several hours and then weighed on an analytical balance. The slime is then removed from the slide in the following manner:

1. Pour 5 ml of distilled water into a porcelain dish.
2. Scrape the slime into the dish with a rubber-tipped stirring rod.
3. Empty contents of dish into a Kjeldahl flask containing 200 mg of KMnO<sub>4</sub>.
4. Add 5 ml of 18N sulfuric acid to the dish, swirl, and pour into the flask.

\*Radiophosphorus results are taken from JHUX-3 and JHUX-4.<sup>3</sup>

\*\*This is a modification of Barry's method for the measurement of radioiodine in biological materials.<sup>4</sup>

5. Again dry the slide and weigh to get the tare weight.

The slime is now ready for digestion. Several glass beads are added to the Kjeldahl flask to prevent bumping, and Hengar tubes are placed in the mouth of the flask. The flask is placed in a holder over a microburner and heated. The liquid is boiled gently until it becomes colorless, since the iodine in the slime must be oxidized to iodate.

After the flask cools, the following procedure is followed:

1. Add about 10 ml of distilled water to the flask, swirl, and pour the liquid into a 50-ml volumetric flask. Repeat this operation and add enough water to bring the level to the 50-ml mark.
2. Add 1 ml of a 1000-ppm KI solution and 2 ml of a 0.1 per cent solution of  $\alpha$ -naphthoflavone in alcohol.
3. Pour the contents of the flask into a 100-ml Nessler tube and bring to the 100-ml mark with water. After 3 to 5 min have elapsed, read the light transmission in a calibrated photoelectric colorimeter. If no dilution is necessary, the reading is for the total iodine present. To determine the iodine present in the slime, divide the amount of total iodine by 6.

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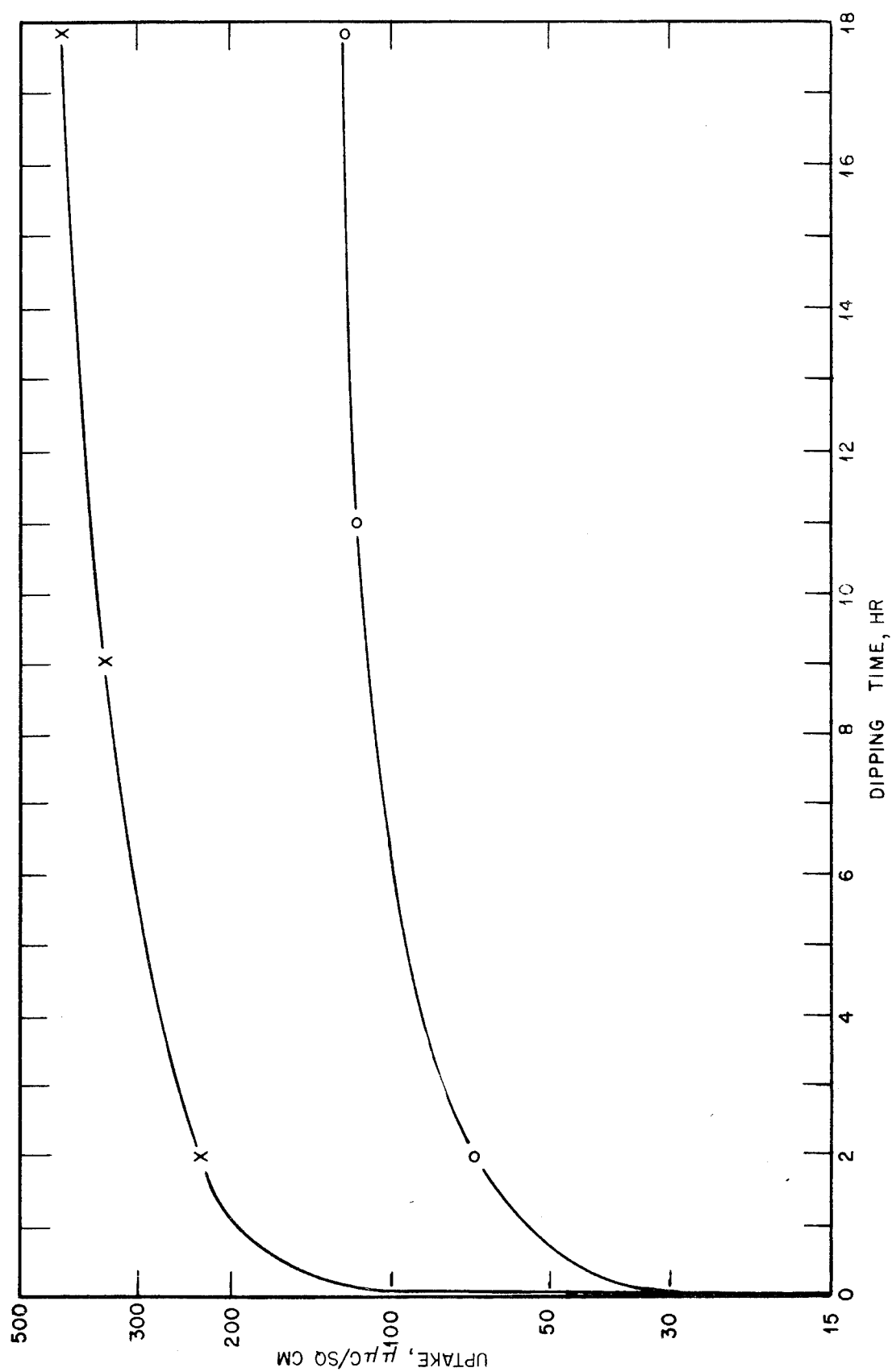


Fig. 1--Adsorption of  $I^{31}$  by slimes dipped for long periods in media containing  $I^{31}$  (pH 7 to 8). Concentration: x, 20.7  $\mu\text{c/liter}$ ; O, 3.3  $\mu\text{c/liter}$ .

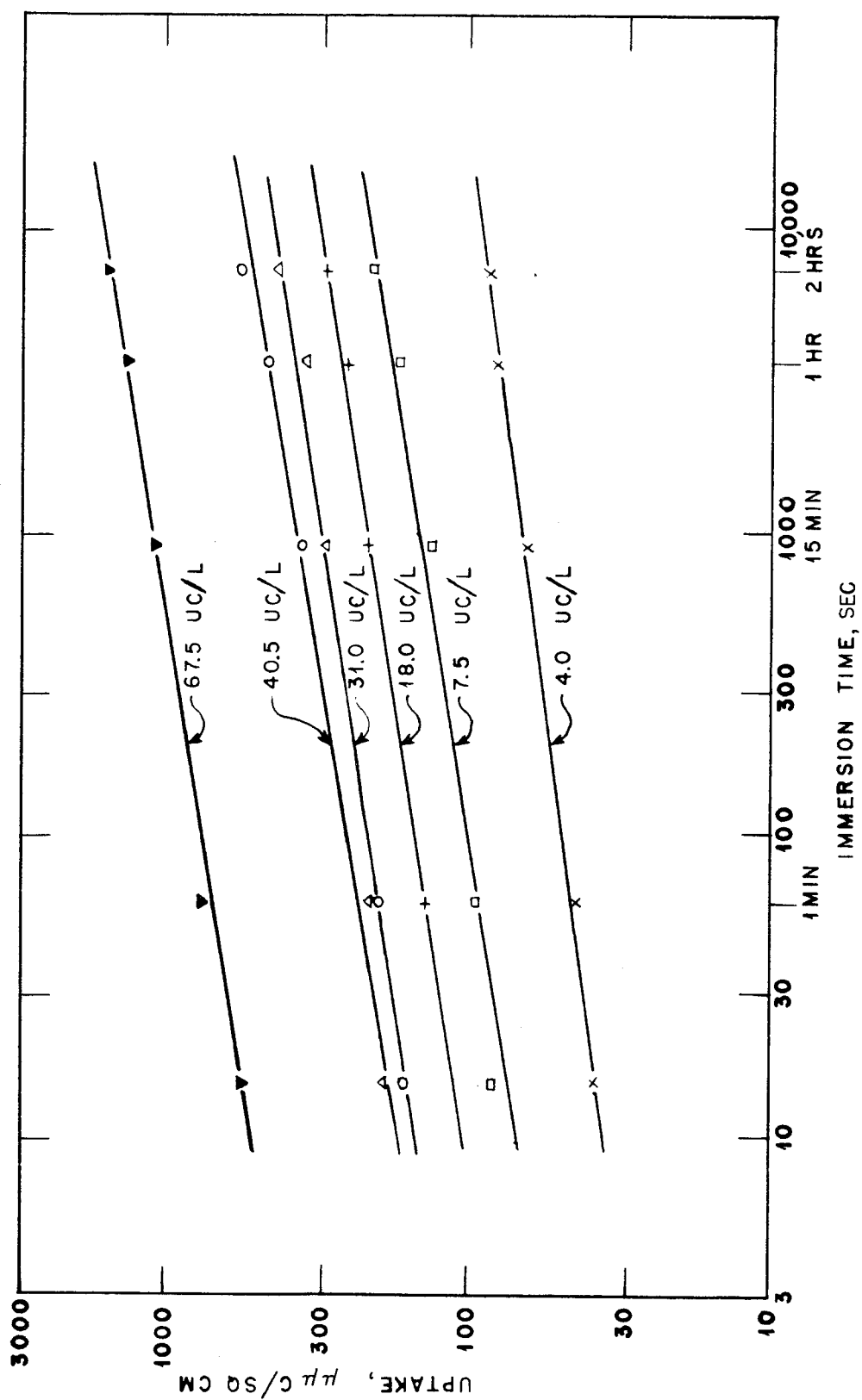


Fig. 2—Uptake of  $^{131}\text{I}$  by slimes at various concentrations of  $^{131}\text{I}$  (pH 5.8).

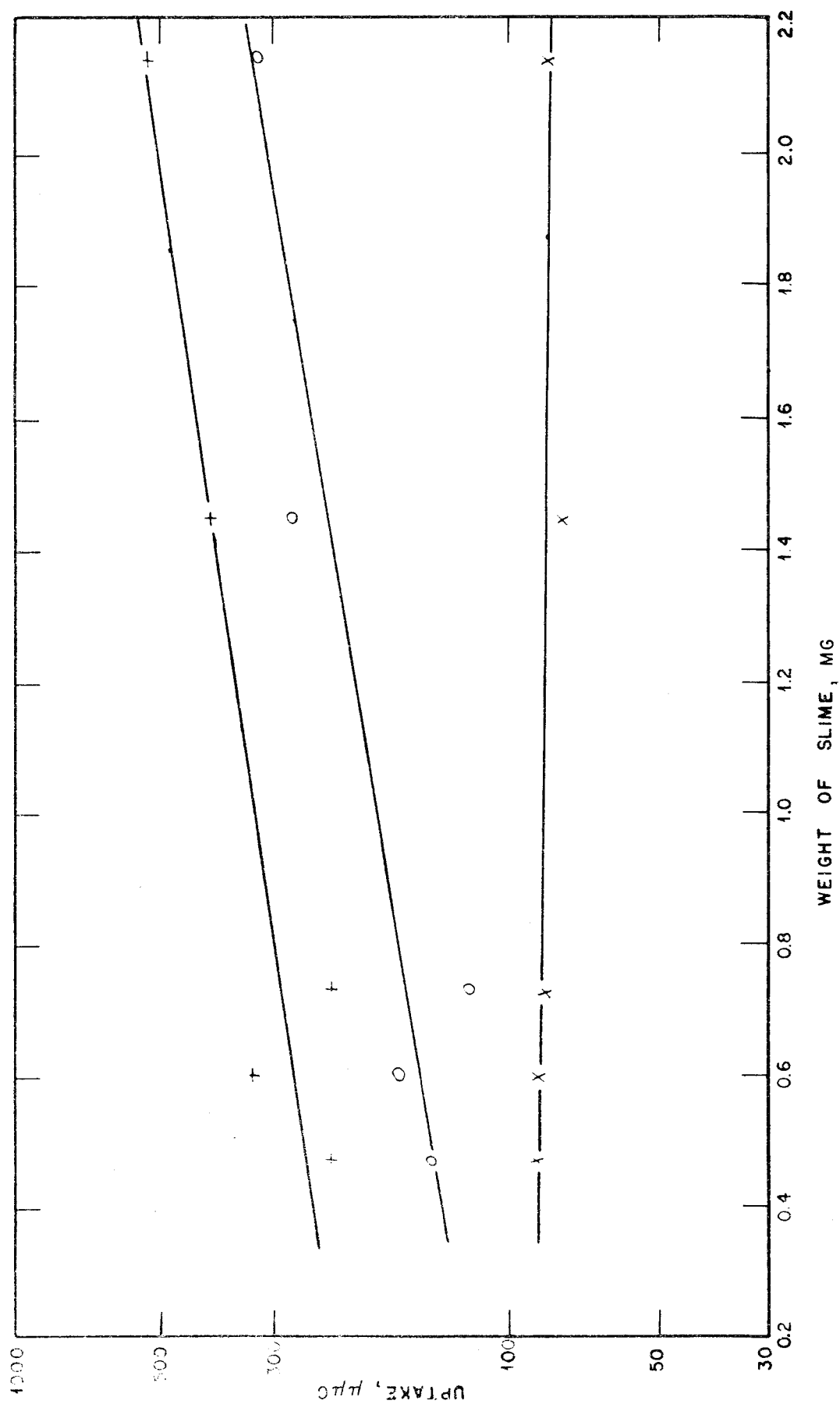


Fig. 3—Variation of uptake of  $^{131}\text{I}$  with weight of slime (pH 5.8; concentration,  $19.9 \mu\text{c}/\text{liter}$ ; area of slime,  $1 \text{ sq cm}$ ). Immersion time: +, 1 hr; O, 1 min; x, 3 sec.



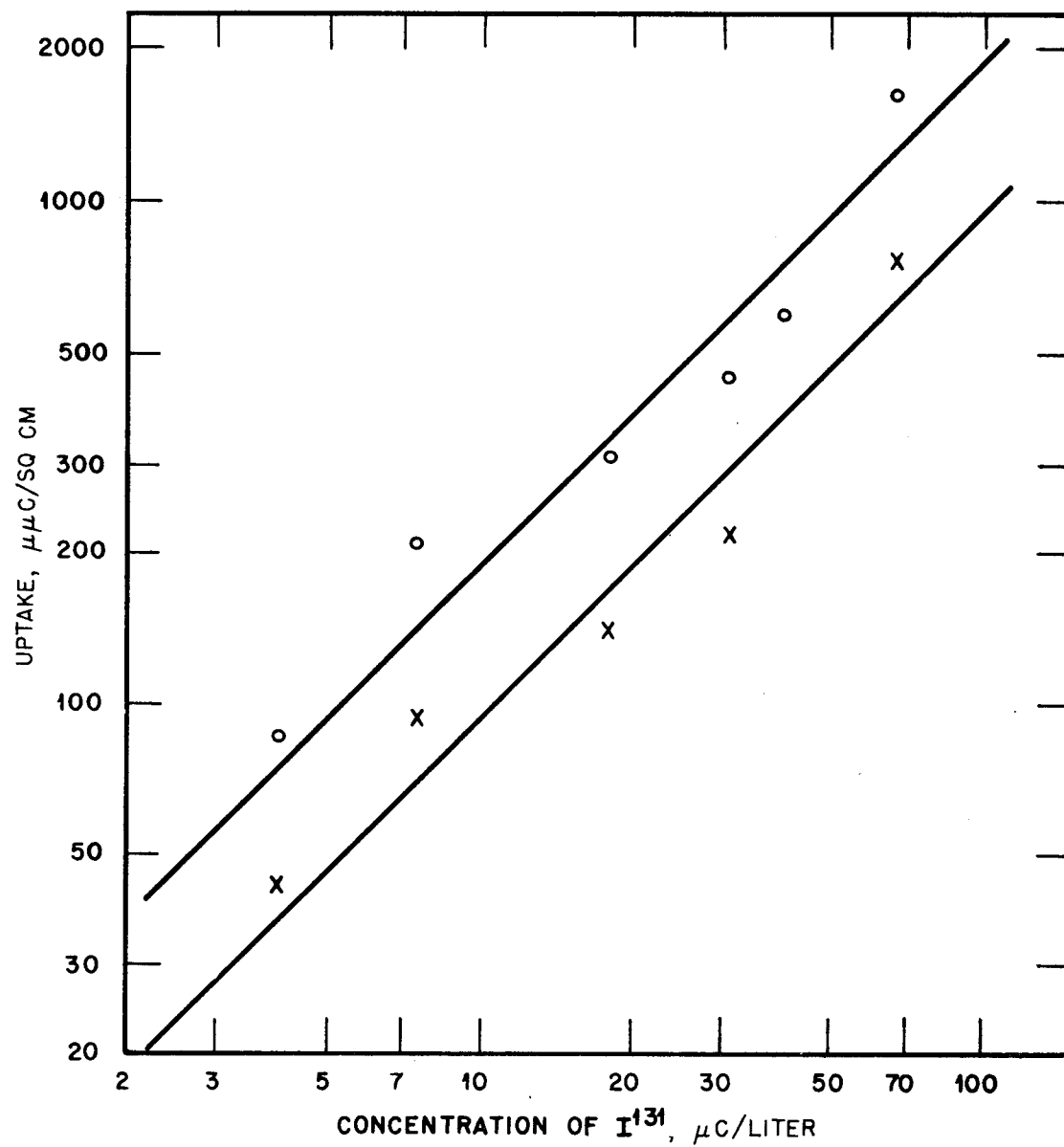


Fig. 4—Variation of uptake of  $\text{I}^{131}$  by slimes with concentration of  $\text{I}^{131}$  (pH 5.8). Immersion time: O, 2 hr; X, 1 min.

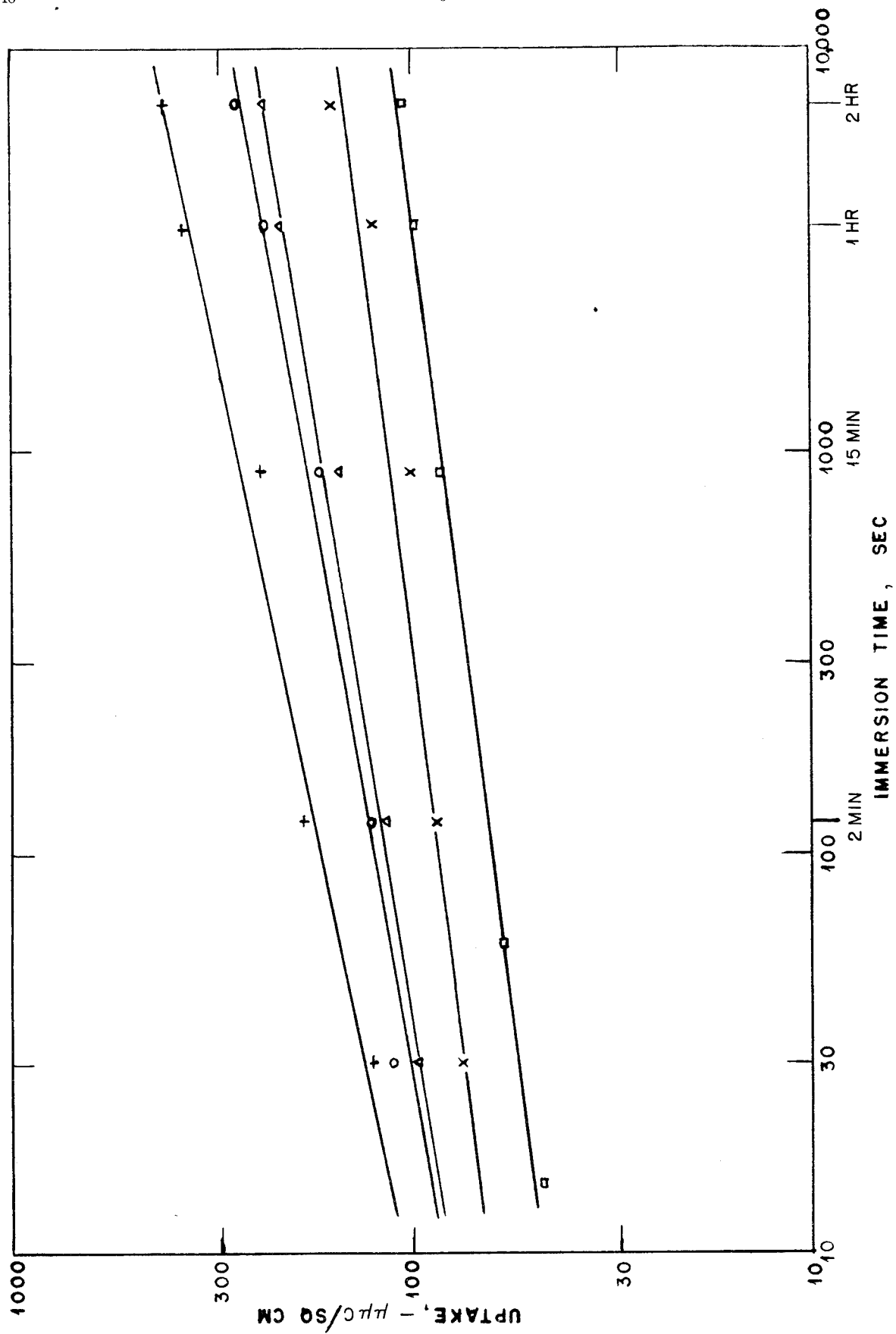


Fig. 5—The effects of pH on the uptake of  $^{131}\text{I}$  by slimes (concentration,  $14.7 \mu\text{C}/\text{liter}$ ).  
 +, pH 6. O, pH 3.  $\Delta$ , pH 9. x, pH 10.  $\square$ , pH 8.

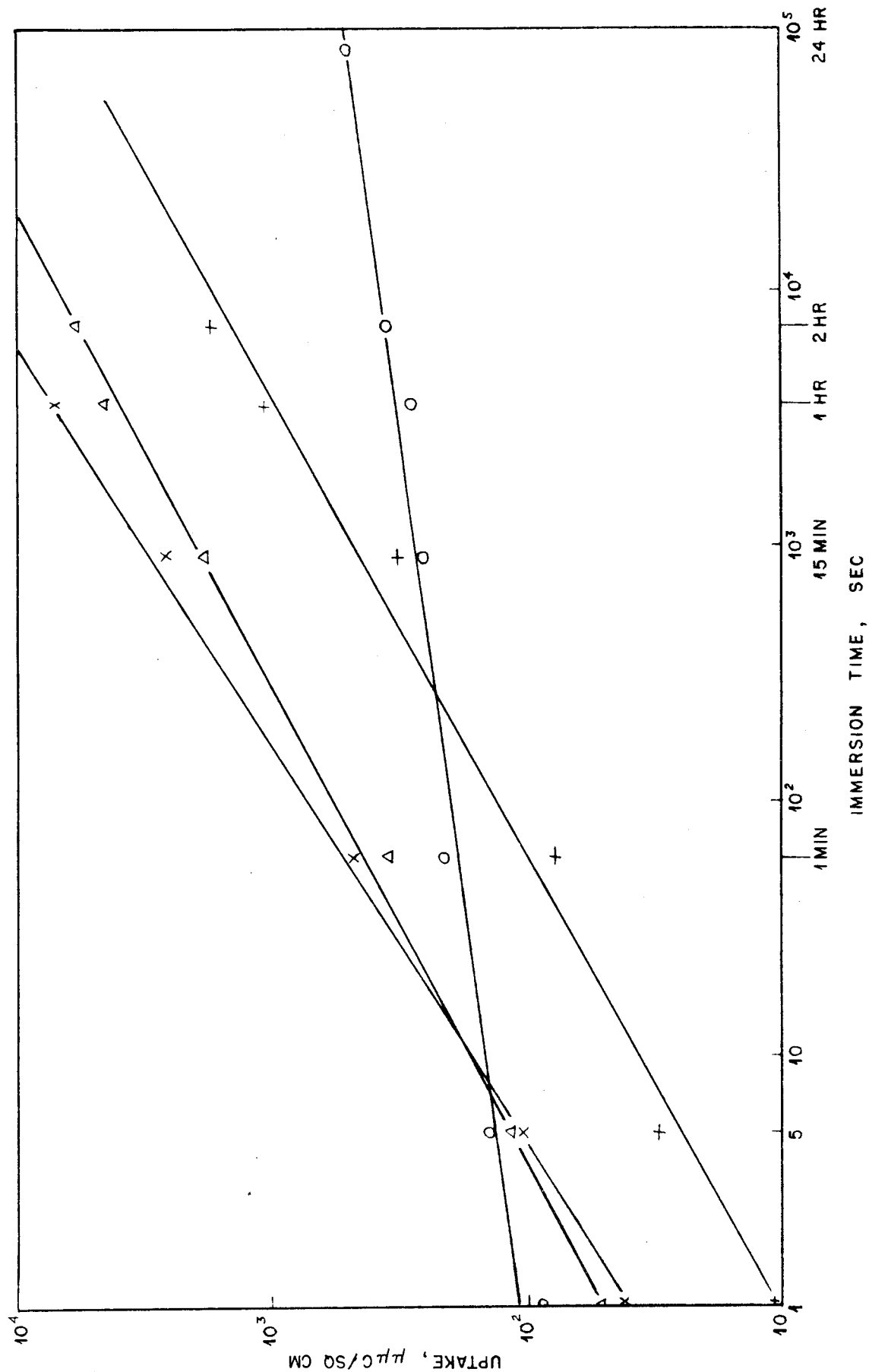


Fig. 6—Comparison of uptake of  $^{131}\text{I}$  by slimes and bare metals (pH 5.8; concentration, 20.0  $\mu\text{c}/\text{liter}$ ). x, lead.  $\Delta$ , copper. +, galvanized iron. O, slime on glass.

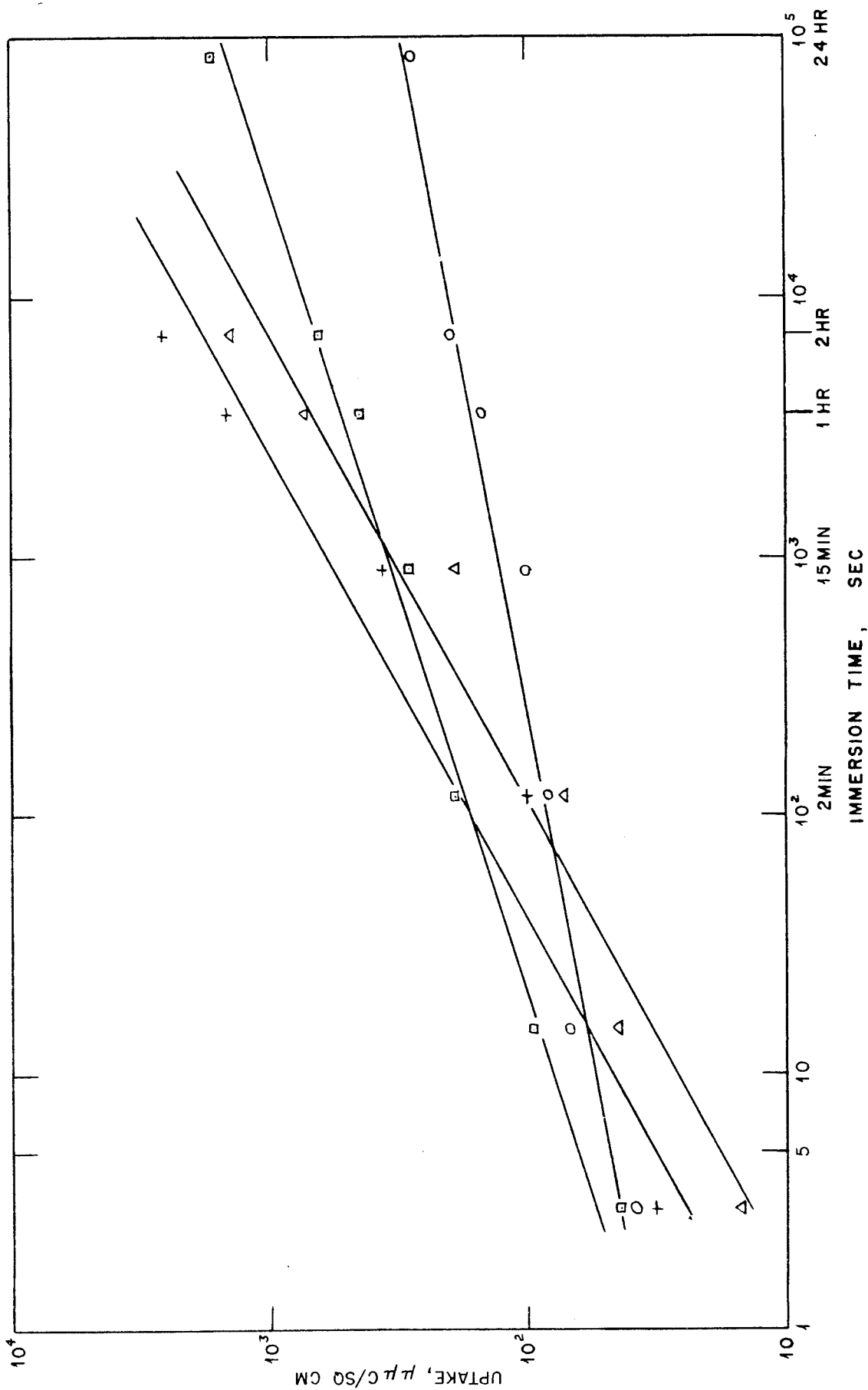


Fig. 7—Uptake of  $^{131}\text{I}$  by slimes grown on metals and slides (concentration,  $13.4 \mu\text{C}/\text{liter}$ ; pH 5.8).

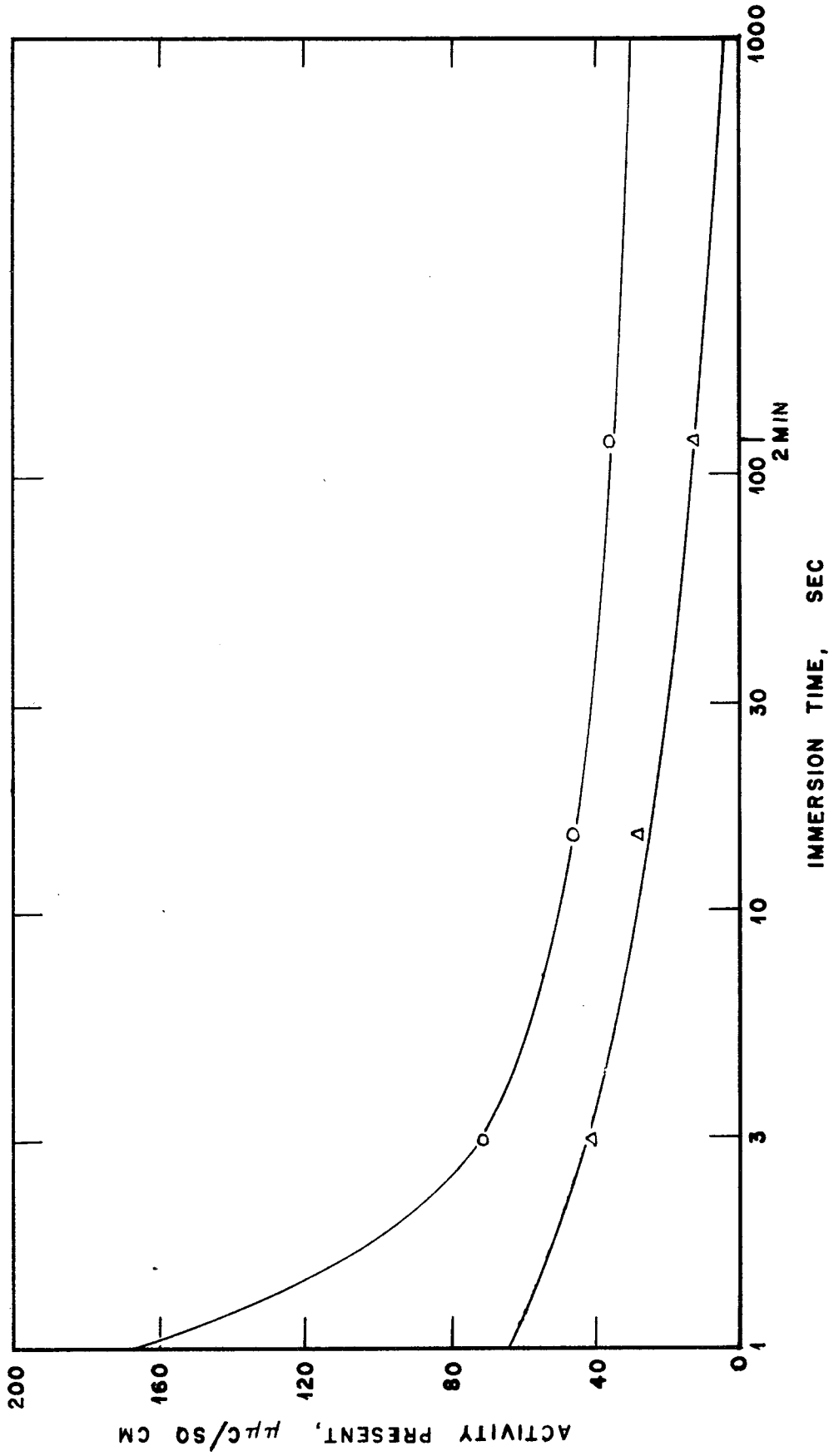


Fig. 8--Removal of  $\text{I}^{131}$  from slimes by immersion in tap water. Activity initially present: slime A,  $.167 \mu\text{C}/\text{sq cm}$ ; slime B,  $.64 \mu\text{C}/\text{sq cm}$ . O, slime A. Δ, slime B.

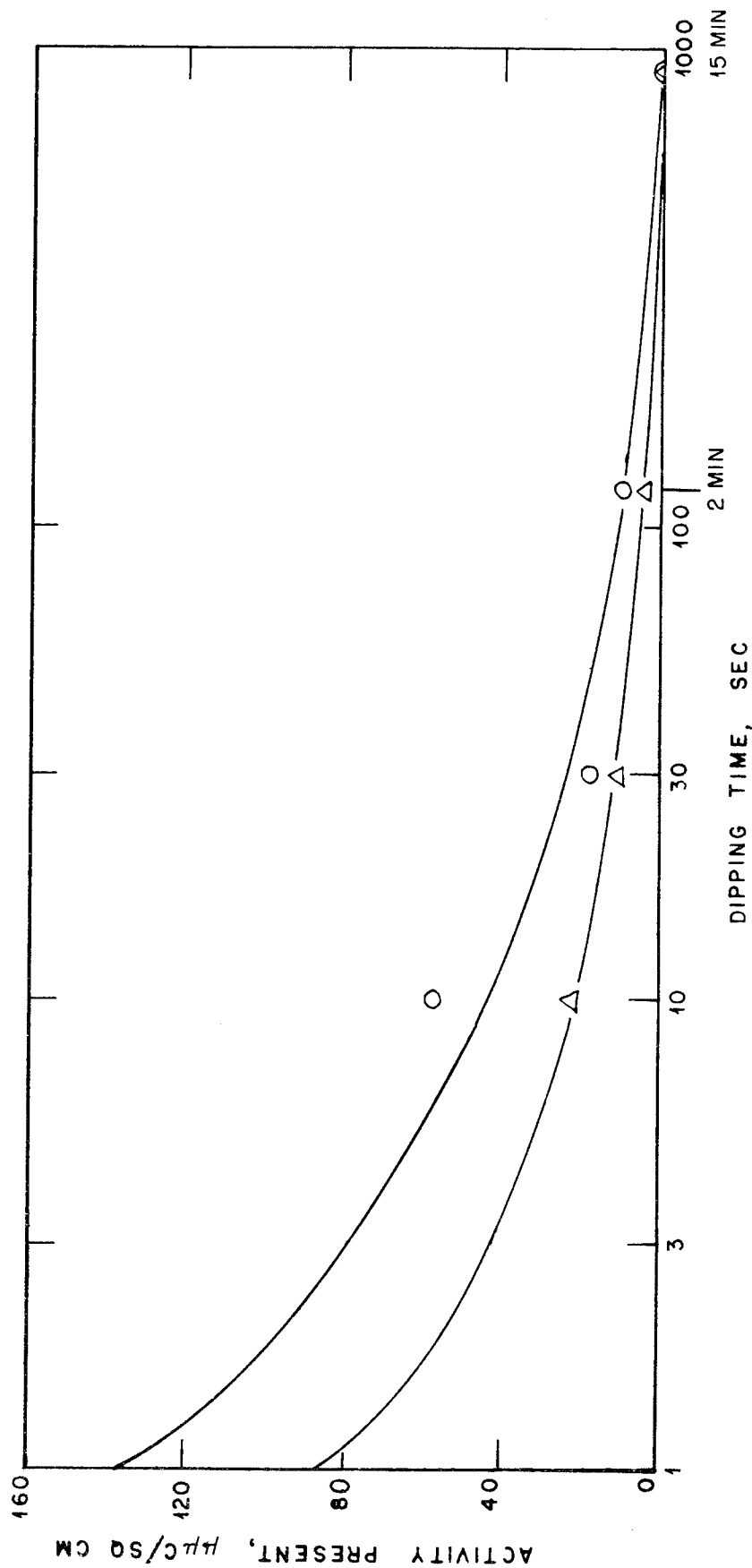


Fig. 9—Removal of  $^{131}\text{I}$  from slimes by repeated dipping in tap water. Activity initially present: slime A', 135  $\mu\text{C}/\text{sq cm}$ ; slime B', 87  $\mu\text{C}/\text{sq cm}$ . O, slime A'.  $\Delta$ , slime B'.

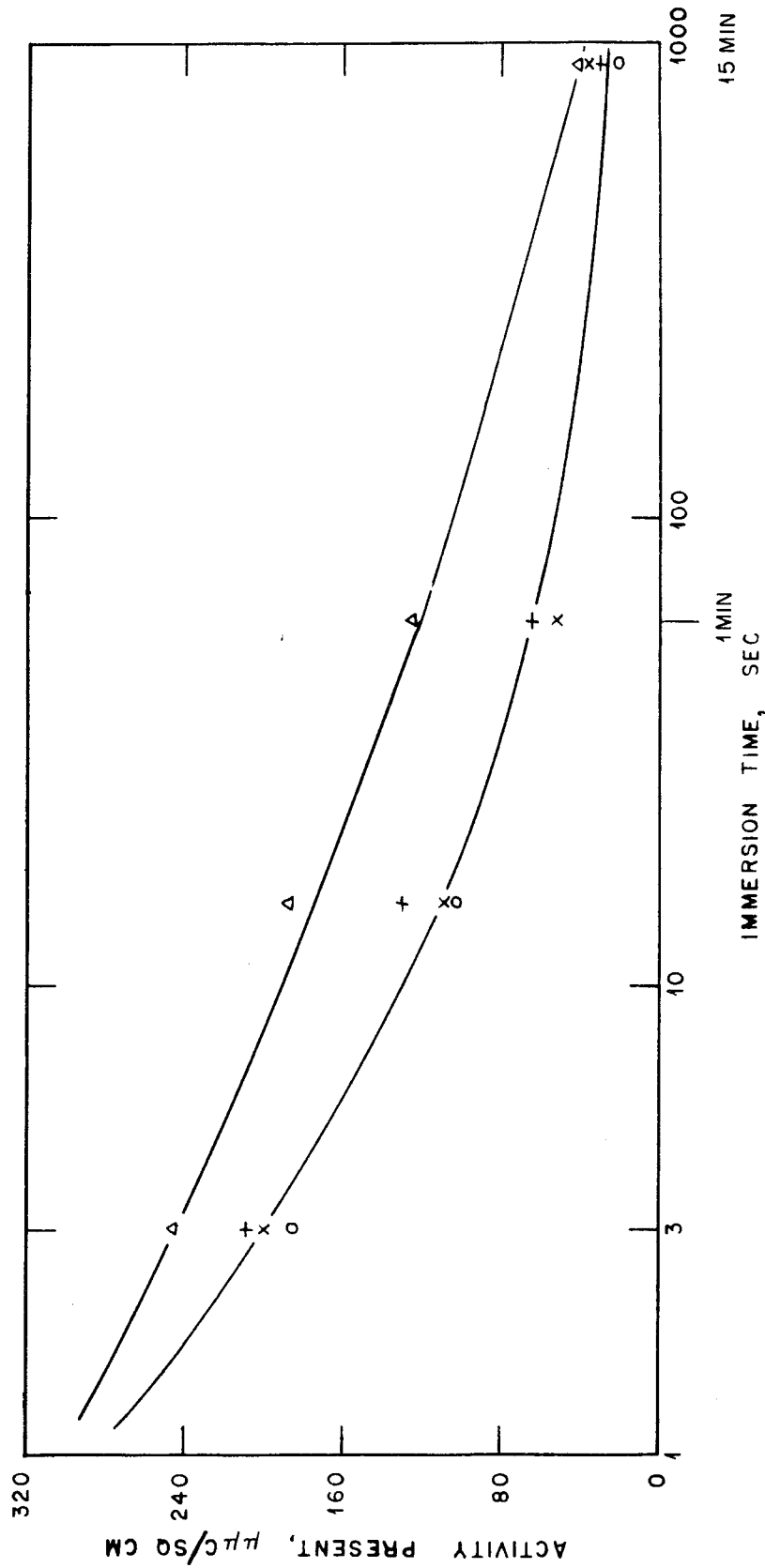


Fig. 10—Comparison of desorption of  $I^{131}$  by various rinses (all slimes previously immersed for 1 hr in  $14.5 \mu\text{C}/\text{liter}$  at pH 5.8). Rinses: x, immersion in tap water, pH 6.8; O, immersion in soapy water, pH 8.0; +, immersion in water plus Alconox detergent, pH 9.2;  $\Delta$ , immersion in dilute HCl, pH 3.4.